

**Collaboration on Development and Validation of the  
AMSR-E Snow Water Equivalent Algorithm**

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**I. Development of Standardized Data Sets**

**A. Satellite Data**

The National Snow and Ice Data Center (NSIDC) has produced a global SMMR and SSM/I Level 3 Brightness Temperature data set in the Equal Area Scalable Earth (EASE) Grid for the period 1978 to 2000. (Armstrong and Brodzik, 1995; 1997). Processing of current data is ongoing. The EASE-Grid passive microwave data sets are appropriate for algorithm development and validation prior to the launch of AMSR-E. Having the lower frequency channels of SMMR (6.6 and 10.7 GHz) and the higher frequency channels of SSM/I (85.5 GHz) in the same format will facilitate the preliminary development of applications which could potentially make use of similar frequencies from AMSR-E (6.9, 10.7, 89.0 GHz).

**B. Validation Data**

**1. Snow Extent - Hemispheric Scale**

The philosophy of this study is to focus on the robust nature of the larger validation data sets which are expected to provide a full range of snow/climate relationships rather than on smaller data sets which may only represent a "snapshot" in time and space.

A primary task in this study is to compare the EASE-Grid version of the NOAA weekly snow extent data with passive microwave test algorithm output. The original NOAA-NESDIS weekly snow charts are derived from the manual interpretation of AVHRR, GOES and other visible-band satellite data. The new NSIDC version of this data set is based on the digital NOAA-NESDIS snow charts, revised by Robinson (1993). These data have been re-gridded to the NSIDC EASE-Grid and currently cover the period 1971 to May 31, 1999.

**2. Snow Water Equivalent - Regional Scale**

The validation data set currently being applied includes data from more than 1,200 stations and transects within the former Soviet Union. Measurements include snow depths at WMO stations and snow water equivalent measured over nearby snow course transects at ten day time intervals each

terrain, and vegetation cover. The transects are typically 1.0 to 2.0 km in length with measurements every 100 to 200 m. These transect data allow the unique opportunity to statistically evaluate the response of an algorithm to a larger spatial pattern than that of a single point measurement. These data are available during both the SMMR and the SSM/I periods allowing pre-launch analysis of both the low (6 and 10 GHz) and high frequency channels (85 GHz) comparable to those which will be available on AMSR-E.

Our initial goal here is to evaluate the accuracy of algorithms under the most controlled conditions possible. To create this best case validation data set, we currently focus on a sub-area west of the Ural Mountains (45-60 deg. N. Lat., 25-45 deg. E. Lon) where station density is maximum (approximately one or more stations per 100 km) the terrain is non-complex (grassland steppe with maximum elevation differences of less than 500 m) and most of the region is non-forested. We have computed forest cover density over a radius of 50 km surrounding each observing station. Daily air temperature is available from the NCEP reanalysis data set.

For each station file, the analysis involves the extraction from the NSIDC mass storage of daily brightness temperature files for the observation date and for the previous two days to provide complete spatial coverage. Algorithm output and station measurements are then compared over the complete period of available data using statistics which include average, maximum and minimum differences, root mean square (rms) differences and total number of pixels available for comparison.

## **II. Analysis**

### **A. Snow Extent**

The 22 year time series (SMMR and SSM/I) allows us to determine the capability of passive microwave data to reproduce the Northern Hemisphere snow extent climatology as represented by the NOAA data. When applying a test algorithm (NSIDC1) based on the difference between the 18 and 37 GHz SMMR (Chang et al. 1987) and 19 and 37 GHz SSM/I (modified Chang algorithm) both data sets show limited inter-annual variability over the period, both indicate maximum extents consistently exceeding 40 million square kilometers and both indicate a decrease in mean-monthly snow covered area of approximately 0.4% per year (Armstrong and Brodzik, 1999). Results clearly indicate those time periods and geographic regions where the two techniques agree and where they tend to consistently disagree. For example, during the early winter season (November-December) as the snow line progresses southward, most passive microwave algorithms appear to significantly underestimate the snow extent in certain regions. The difference is greatest at the lower elevations across both North America and Eurasia where the snow cover is more likely to be shallow (less than about 3.0 cm) and may often exist at the melting temperature. Mapped images showing these differences were contained in our 1999 report.

Recent results show this relationship by another method. Figure 1. shows the average annual pattern of the difference between output from the NSIDC1 test algorithm and the NOAA satellite data. The largest differences are during November and December when the algorithm tends to underestimate the snow extent. The apparent undermeasure of shallow snow by this type of passive microwave

algorithm is likely due to the fact that thin snow cover does not provide a scattering signal of sufficient strength to be detected by the 37 GHz channel. Therefore, in this phase of the study we apply a snow cover algorithm (Nagler, 1991) which includes the 85 GHz channel in order to determine if the apparent underestimate of snow extent during the fall season could be reduced.

Figures 2 and 3 contain scatter plots which compare total snow covered area (Northern Hemisphere, 1987-1999) for two different passive microwave algorithms (SSM/T) and the NOAA data. In Figure 2, the NSIDC1 algorithm shows the typical under measure in the fall while in Figure 3, the Nagler algorithm actually exceeds the snow extent as indicated by the NOAA data. Minor adjustments to this algorithm would bring this relationship nearer to the one-to-one line. The Nagler algorithm also indicates an overmeasure in winter while corresponding closely to the one-to-one line for the spring period.

### B. Snow Water Equivalent

A comparison of passive microwave algorithm output with the station data is shown in Figure 4 which summarizes preliminary results for the NSIDC1 algorithm for a 12 year period. Figure 5 shows an example for an individual winter season (1988-89). This example shows results from the NSIDC1 algorithm (19H-37H), the Goodison algorithm (19V-37V) and the Nagler algorithm (19V-37V, 37V-85V). All three algorithms tend to underestimate the SWE, with the H pol algorithm being closer to the measured values in this and most all other examples run for this study region. In this example the 85 GHz data are only available for the months of November, December and January but during the later part of that period the Nagler algorithm does represent the best match with the measured data of the three algorithms.

Our results indicate that incorporation of the higher frequency channels (e.g. 89 GHz on AMSR-E) will enhance SWE retrievals. However, it is known that these high frequency channels are sensitive to atmospheric effects. We have evaluated the methodology proposed by Nagler (1991) to limit retrievals to those days with the least amount of cloudiness during the sample period. The approach is simply to subtract the 85 GHz from the 37 GHz channel and run the algorithm on that day for which the difference is the greatest. Although we have not quantified the degree to which this improves results with respect to more accurate snow retrievals, it is apparent from all examples we have observed that this method is extremely effective in filtering thick cloud cover. This result is readily apparent when comparing time series images of regions outside the snow covered area and noting the location of west to east moving precipitating storm systems reflected in the algorithms using lower channels only. These same storm systems are removed as a result of the application of the 37GHz - 85GHz filter.

### C. Forest Cover

Because of the detailed land cover data available for this region, we anticipated being able to develop a method to apply algorithm corrections as a function of fractional forest cover using an approach similar to those applied by Chang et al. (1996). Figure 6 shows an example of a typical passive microwave/station SWE difference histogram and the associated relationship between forest cover

density and the passive microwave/station SWE difference. The tendency for the algorithm to underestimate SWE increases significantly as the percent forest cover begins to exceed 40 to 50%. In order to better quantify this relationship we apply the forest density data set for this region to verify the relationship between forest density and 37GHz polarization difference suggested by Choudhury (1999, personal communication). Results of our initial effort to quantify the relationship between polarization difference and percent forest cover were not particularly successful. Figure 7 shows this comparison and the large amount of scatter in the data. The large amount of scatter may be the result of mixed pixels (land and water). We will re-evaluate this relationship using land-only pixels and by using other land cover data sets.

### **III. 2000-2001 Work Plan**

#### **A. Snow covered Area:**

We will continue the testing of algorithms which include the 85 GHz channel (shallow snow) as well as a 37 GHz polarization difference approach (wet snow) to quantify the degree to which these additions enhance algorithm ability to accurately represent snow extent. These tests will continue to involve the NOAA visible-band satellite data as well as MODIS data when they become available.

#### **B. Snow water equivalent:**

Using methods similar to the case studies shown in the examples above, we will complete the production of individual difference maps and associated analysis for the Russian study area for the full winter seasons from 1978 to 1990. We will also attempt to acquire station data since 1990 through collaboration with Dr. Vyacheslav Razuvaev, All-Russia Institute of Hydrological Information, Obninsk, Russia. We will run the SWE algorithm evaluations described above using at least one additional validation data set, either the NOHRSC United States Composite Snow Water Equivalent Maps or USDA/NRCS SnowTel and Snow Course data.

### **IV. References**

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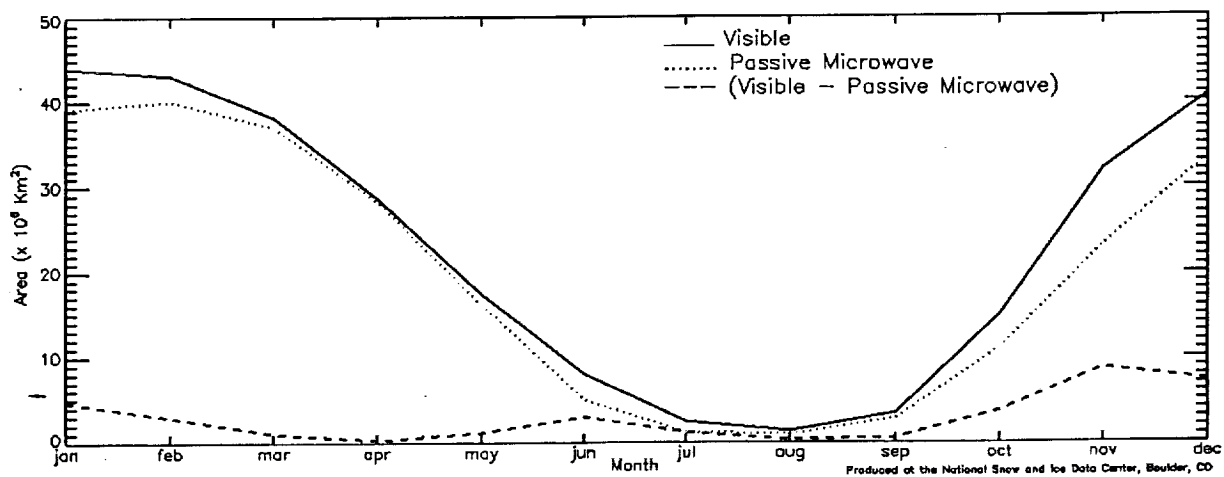


Figure 1. Northern Hemisphere mean monthly snow-covered area derived from visible (NOAA) and passive microwave (SMMR and SSM/I) and the difference between the two, 1978-1999.

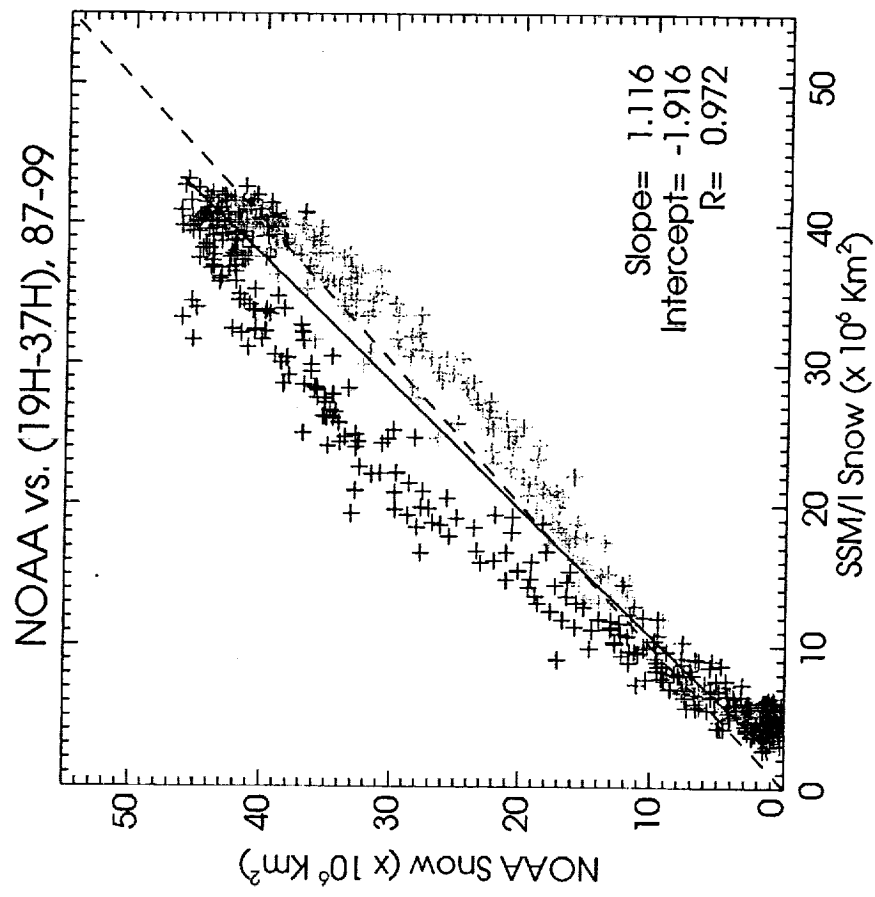


Figure 2.

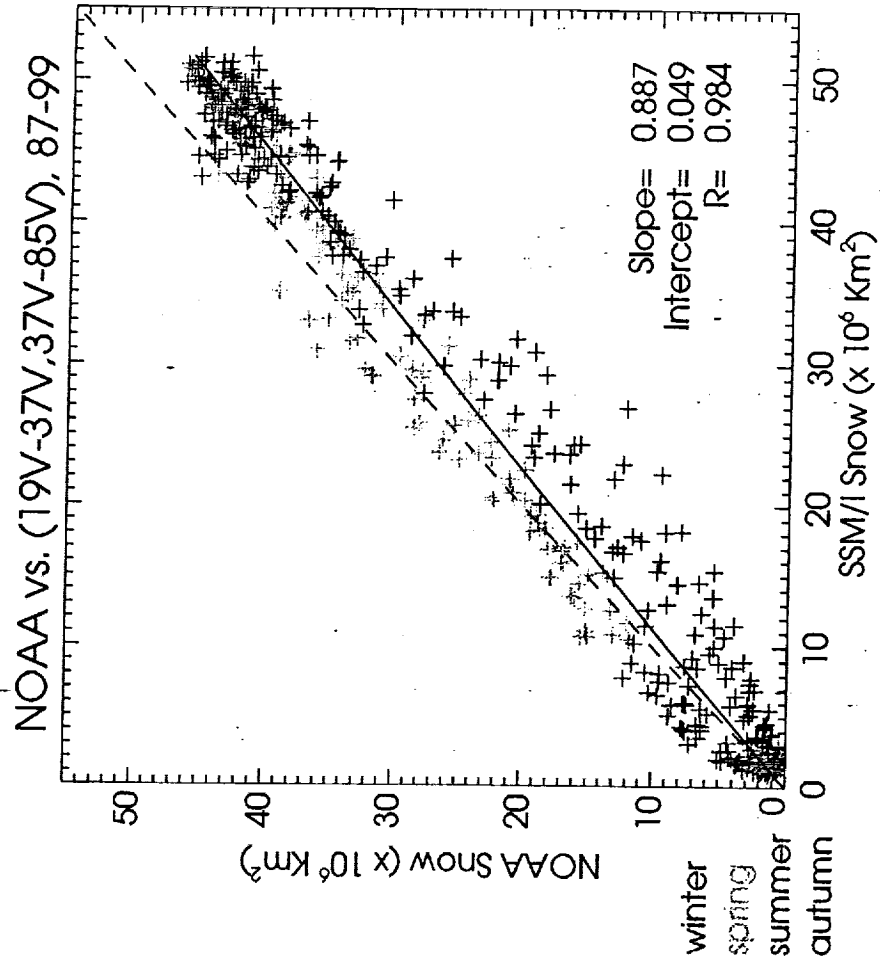


Figure 3.

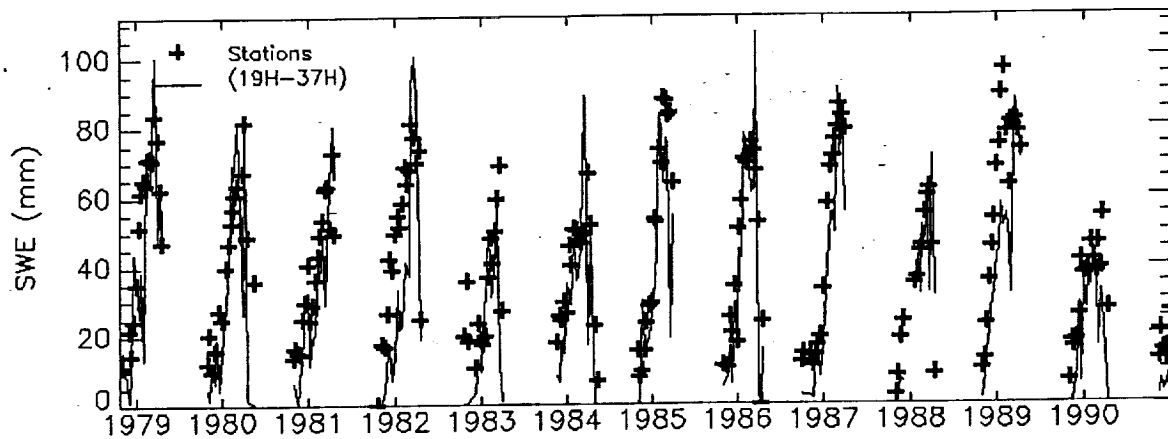


Figure 4. Average of total study area (FSUHS subset) snow water equivalent vs. passive microwave snow water equivalent using horizontally polarized difference algorithm, 1978-1990.

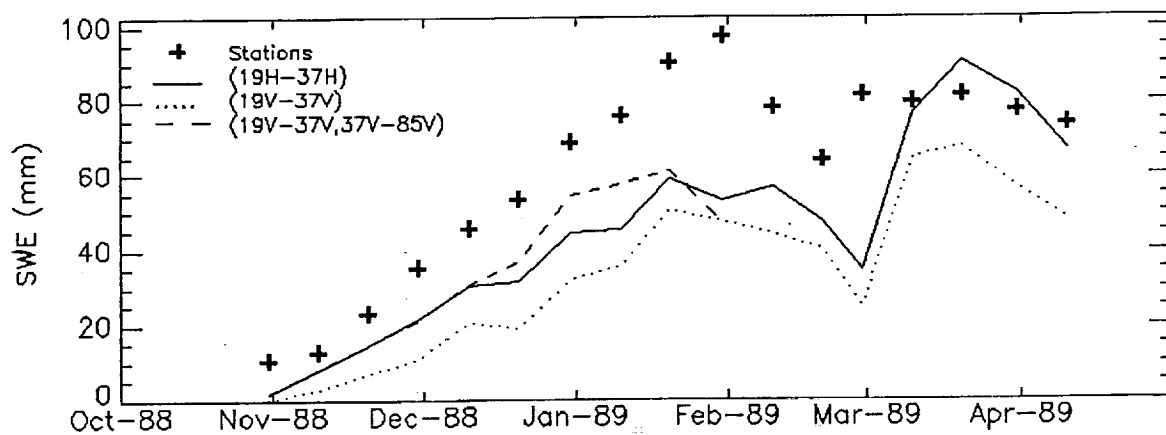


Figure 5. Average of total study area (FSUHS subset) snow water equivalent vs. passive microwave snow water equivalent from three algorithms, 1988-1989.

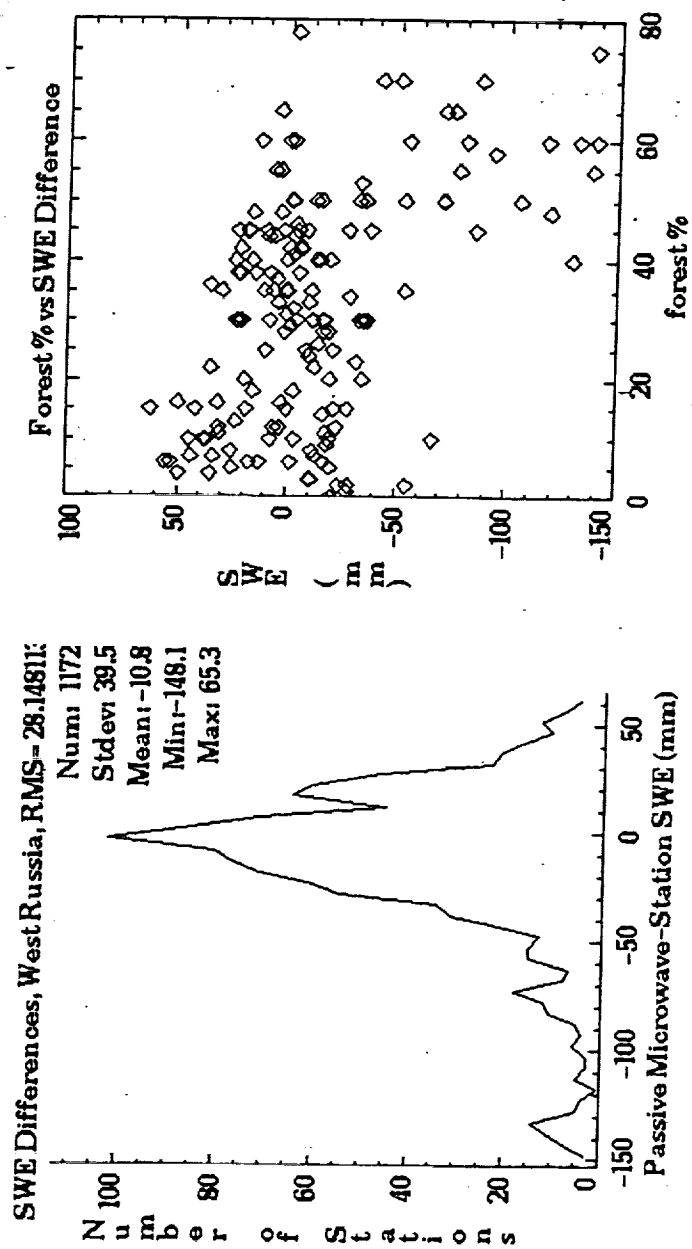


Figure 6.



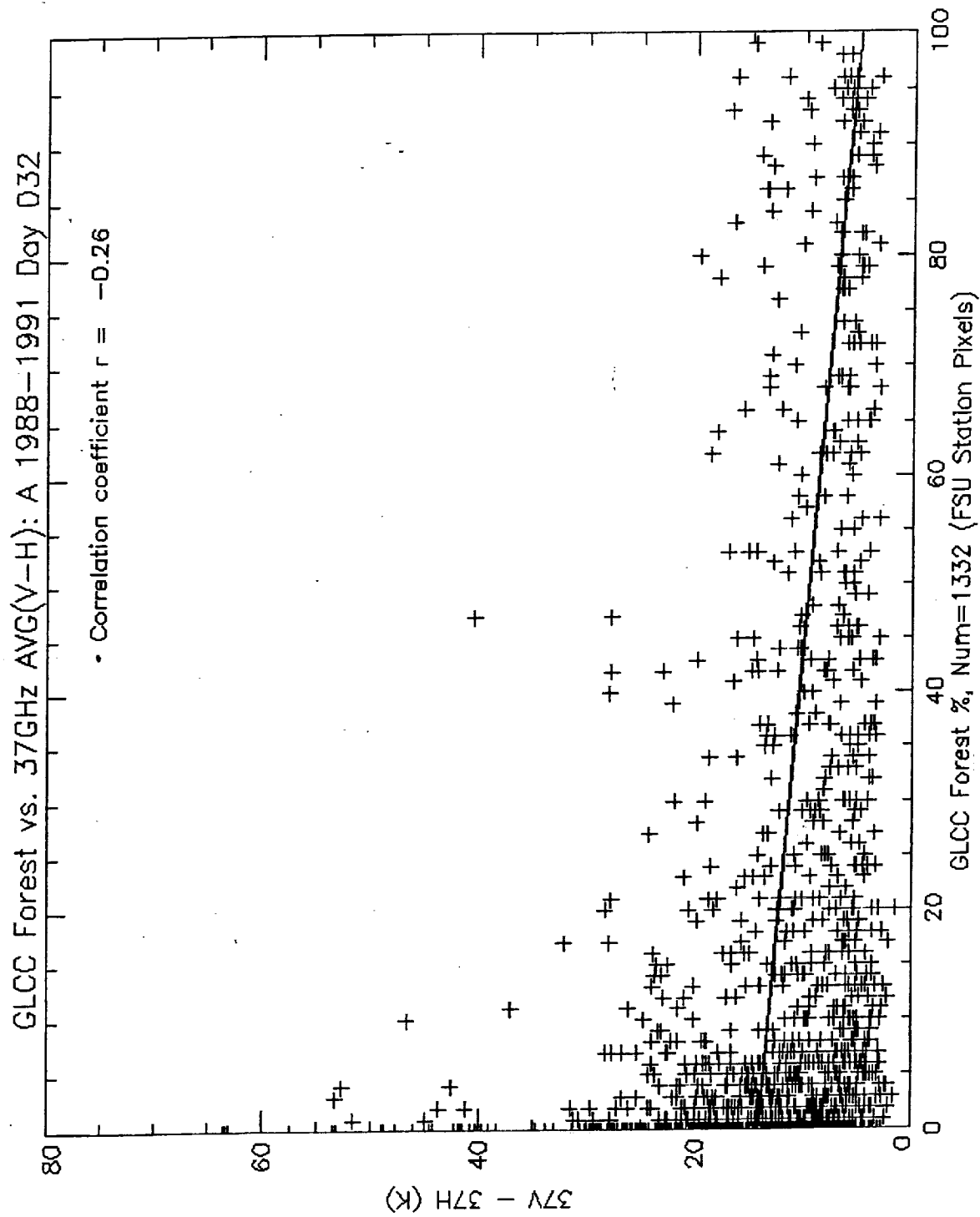


Figure 7. Comparison of forest density based on the magnitude of the 37 GHz polarization difference and forest density derived from the Global Land Cover Classification (GLCC) data set for February 1 for four years, 1988-1991..

